EDUCATIONAL DESIGN RESEARCH IN MOZAMBIQUE: STARTING MATHEMATICS FROM AUTHENTIC RESOURCES

Pauline Vos¹, Tiago G. Devesse², and Assane Rassul²

¹University of Groningen, Netherlands
²University Eduardo Mondlane, Mozambique

This article describes a research on learner-centred instruction in Mozambique, Africa. A starting point was the use of real-life resources, such as traditional art craft objects and authentic newspaper clippings. The study used a method which is termed 'design research'. This method aligns theory with practice and is geared towards improving educational practice. In two sub-studies, on geometry and on statistics, learner-centred instruction was facilitated through the use of worksheets with open-ended questions tailored for group work. The designs were tested in cyclic interventions and formatively evaluated through observation reports, interviews and assessment of learners’ work. A decentralised, student-centred learning ecology proved to be feasible in overcrowded classrooms, typical in African education.

INTRODUCTION

In Mozambique all sectors of education suffer from weaknesses, whether it be primary, secondary or tertiary education. Generally, mathematics education can be characterized by teacher-centred instruction, chorus-recitation, shortages of materials and facilities, un(der)qualified teachers, overcrowded classes, and a curriculum with much theory and few links to learners’ lives. As a result, there are cognitive, instructional and affective problems. Regarding the cognitive problems in the mathematics classes, in general, learners learn to memorize formulas and algorithms, needed for the immediate solution of exercises. For many learners, there is neither logical sequence, nor any clear relationship between concepts. Mathematics is taught as a deductive discipline, starting from definitions. For example, the official grade 10 mathematics curriculum document prescribes the drill of formulas, stating that the formulas for area and volume of a cone should be imprinted by frequent repetitions (Ministério da Educação, 1995). As a result, learners know mathematical formulas without understanding them, leading to short-term retention and low motivation.

Instructional problems in Mozambican mathematics classes are related to the low number of qualified teachers and to lack of instructional materials. The majority of the teachers in primary education completed fewer than twelve years of education. More than 80% of the mathematics teachers in secondary education are unqualified. The few qualified teachers only teach the highest grades (grade 11-12). Also at tertiary level, most lecturers have a degree equal to the level of the courses they teach. As for the lack of instructional materials, there are few books, teaching manuals and other publications. For governmental primary and junior secondary schools, the Ministry provides schools with officially mandated textbooks, but the
number of copies is insufficient to satisfy the needs of all learners (Mira, 2000). The shortage of books at senior levels forces teachers to use foreign books and make learners copy the content (either from the blackboard or by reading out aloud). With the shortages being structural, teachers have become used to the situation. Even in cases of sufficient facilities, teachers still stick to the routine of orally transmitting definitions and theorems through chorus-recitation.

Mathematics education in Mozambique, like in many other countries, also faces problems in the affective domain. For many learners, the language of teaching (Portuguese) differs from their mother tongue. Also, the content of mathematics education does not link with learners’ context. Mozambican learners perceive mathematics as being of little use for understanding the world around them (Januário et al., 2002). They see mathematics as strange, as coming from another world and being imposed upon them. Moreover, many learners live with uncertainty of their abilities and with fear of failure, especially in mathematics.

In this situation, a research in mathematics education was started, aiming at integrating authentic experiences from learners’ context with mathematical concepts. The objectives of the study were manifold. First, we wanted to show, that modern Mozambican society is powerful and rich in resources, to such an extent that it can provide mathematics education with many applications. Second, we wanted to create a learning environment, in which the teacher-centeredness was reduced. For this objective we planned to design prototype materials in such a way that whole-class lecturing could be largely avoided, and discussion among learners enhanced. If the materials were well-designed they could set an example for how dynamic classrooms can be organized. Finally, with lesson materials that complied with the mandated textbooks, we hoped to demonstrate that innovative instructional approaches can be embedded within the frame of the central curriculum demands.

DESIGN RESEARCH

The Mozambican complexity of teaching and learning asked for a research approach, which faces the conditions of learning. Thus, the study was conceived as a design research. Design research in mathematics education goes back to the writing by Hans Freudenthal (1991), who explained mathematics as a human activity and who insisted on design research as the core of mathematics education.

Burkhardt and Schoenfeld (2003) also advocate design research. They state that traditional educational research does generally not lead to improved practice, due to lack of credible models. However, an engineering approach to design educational processes leads to refined ideas and materials, which are robust across a wide range of contexts. Also Wittmann (1995) suggested that the tension between research and practice can be eased through the design of substantial learning environments, exemplified by arithmetic puzzles that lead to lively classrooms at primary level.

Design research is a methodology that goes beyond the teaching experiment, in which one attempts to establish an existence proof, which shows that ‘something’ can
be done in class (Lesh & Kelly, 2000). Cobb et al. (2003) explain how in design research educational researchers engineer improvement by bringing about new forms of learning in order to study them. They introduced the idea that design research serves to study a learning ecology, to emphasize that learning takes place in an environment consisting of interacting systems and not as a set of activities or as a list of factors. A learning ecology contains aspects such as the teacher and his/her instruction, tasks and problems, modes of dialogue, ‘norms’ for participation in discussions, tools and aids and the way teachers conduct whole-class communication. Using a design approach enabled us to include socio-cultural and situated analyses into the research, going beyond cognitive and psychological aspects.

The current research was inspired by studies carried out in the United States and the Netherlands (Breiteig, Huntley & Kaiser, 1993; Gravemeijer, 1994), in which mathematical modelling activities were tailored as levers for the construction of conceptual understanding. It was guided by the following research question: to what extent can authentic resources be a starting point for assisting learners in the effective formation of concepts. The research comprised two sub-studies. The first focused on geometry at grade 10 level. It started from locally produced art craft objects, such as drums, baskets, huts and fish traps (Figure 1). This study was carried out by the second author (Devesse, 2004).

Figure 1: Example of a river fish trap (Niassa Province, Mozambique)

The second sub-study focused on Statistics. It started from newspaper clippings, which were cut from the local daily paper Notícias and other Mozambican publications, with themes such as suicide, domestic violence, maize prices and employment. The target group consisted of university students in the Social Sciences. This study was carried out by the third author (Rassul, 2004). The first author was both supervisor and research assistant in the two sub-studies.

METHODOLOGY

The research was organized in four phases: Analysis, Development, Testing, and Evaluation. In the Analysis phase, contexts of learning mathematics in Mozambique and anticipated problems were analysed. This phase also contained an orientation on the creation of worksheets, a phenomenon generally out of sight in Mozambican education, despite the general availability of photocopiers and printers. In the planned design, most instruction would be conveyed in written form. For inspiration, the second and the third author made a visit to The Netherlands to study the use of photocopies and textbooks as part of instructional methods. When learners work with paper-based materials, classroom communication is no longer centred on the teacher. The contrast with Mozambique was evident.
In the Analysis phase, a number of instructional principles were formulated:

- Mathematics as a human activity, starting from experiences (not from definitions) and developed through worthwhile activities.
- The use of worksheets for group work for facilitating learner-centeredness. The worksheets were to include writing space, giving the researchers written evidence of learners’ performance.
- The use of open-ended questions for discussions between learners. Of course, not all questions were open-ended, but we were eager to include a large number of discussion questions into the worksheets. These questions asked for higher order thinking skills.
- The use of abundant authentic pictorial illustrations. Photographs of art craft objects were included for visualization into the geometry materials. In the statistics study, the newspaper clippings were scanned and pasted in their authentic shape into the worksheets. In this way, learners would immediately see that the themes were authentic and not primarily created for educational goals. The authenticity would show them that they were dealing with themes from their own daily life, from their cultural heritage or related to their professional future.
- For the geometry study, which was geared towards a lower level of learning, we included an additional instructional principle: the integration of manipulatives to enable learners to really hold the objects in their hands and learn about mathematical properties through many senses.
- For the statistics study, we included the integration of computers (spreadsheets) to enable the handling of authentic data.

The second phase was the Development phase. This started with gathering inspiration. For the geometry study, typical art craft objects were found at craft markets and at the Natural History Museum in Maputo (the capital city of Mozambique). For the statistics study, a large number of newspaper articles were cut out. Simultaneously, curricula were studied to analyse to which mathematical concepts the resources could be related, and at which level these would best suit for a series of lessons. It was decided that central curriculum concepts in the geometry study would be: cylinders and cones, which are taught from grade 7 onwards. The central curriculum concepts in the statistics study were: mean, binomial distribution, confidence intervals, sample size, and graphic representations. In this phase, we decided on the target groups. For the geometry study, we decided to contact two different lower secondary schools in Maputo and ask whether we could organise interventions at grade 10 level in collaboration with teachers there. Because we came as an external research team, we decided to limit the lesson series to four hours of contact time. For the statistics study, we decided to stay within our own university because the third author is lecturer of Statistics at the Faculty for Social Sciences. He could organise interventions in the second year Statistics course for students of Political Sciences, Anthropology and Sociology, in collaborations with two tutors. The contact time of this intervention could be sixteen hours.
The first prototype worksheets were validated in an expert appraisal with subject specialists. This made us limit the rigor of the terminology (to keep the language accessible) and include the required formula for circumference and area (to avoid memorization exercises). This yielded the second version ready for testing.

The Testing phase comprised an iteration of cyclic interventions. For example, in the geometry study, three different interventions were organised. Each subsequent intervention had a larger scale. The formative evaluation of an intervention lead to improvements of the worksheets used in the ensuing intervention. The first intervention was a trial with five learners and served to gain confidence with the approach. The second intervention was carried out in a half-size class (22-25 learners, grade 10). A formative evaluation showed that there were obstacles: the practicability was still insufficient (some learners had no experience with scissors, making some activities cumbersome and some models imprecise), and the efficiency towards learners’ understanding needed fine-tuning (learners had a lower level of understanding of cones than anticipated). The first problem was resolved by deleting scissors exercises and adding pre-cut shapes; the second problem was addressed by adding more tasks on comparing different cones.

The final intervention in both the geometry and the statistics study took place in a crowded classroom, typical of African educational contexts (n=55-60), with groups of three to five learners. The observations were recorded in field notes and photographs. Each intervention was concluded with semi-structured interviews with randomly selected learners. The interviews were audio taped and transcribed. In the Evaluation phase, the instructional materials, the observation reports and the interviews were summatively evaluated in light of the research question.

RESULTS

We ended up with a rich database, of which we can only present a small selection in this paper. The research question asked: to what extent can authentic resources be a starting point for assisting learners in the effective formation of concepts? The interventions showed us, that the authentic resources in themselves did not directly ask for mathematical activities. However, these resources were useful as curtain raisers in the instructional design. The resources ignited interest and created a link between extra-institutional experiences and mathematical content.

For example, the university students had already studied many newspaper articles, but this had not helped them develop underlying statistical concepts. Now, the worksheets asked them to think beyond a newspaper phrase, for example: “20% of all women have been victim of sexual harassment during childhood”. Students were asked to interpret this phrase and compare probabilities on different samples. This lead to the discussion on dependent probabilities and on a required randomness of samples:

“If there are five sisters, and some men in the family are a problem, then you can have (that) all were abused.” (Observations on group work, Worksheet 1, Statistics study)
An example of the discussion on sample size:

“You cannot just put any five women together, and say: one of them was harassed. Maybe not one of them was harassed. Or maybe all were harassed. It is an average, so maybe if you take all women in Maputo, then one in five is harassed. But you will not know which ones.” (Observations on group work, Worksheet 1, Statistics study)

The newspaper articles were rich in statistical resources. They enabled us to design questions that made the learners grapple with underlying statistical concepts. The authenticity of the themes triggered students’ motivation by revealing how statistics matters for their professional future:

Student B (from the Interviews, Statistics study): The first year Statistics course, it was limited to doing calculations, using formulas and very little interpretation. But these exercises (points at the worksheets) are more involving, because we are studying Social Sciences, and not Engineering or Economics. These exercises are more important than the classical ones, they give a better opening and more understanding.”

In the geometry study, we observed a teacher holding up a miniature fish trap in front of the blackboard, surprising the (urban) learners with their (rural) cultural heritage:

Episode 3 (from School B, lesson 2, Geometry study): 
19. Teacher: Do you know the name of this art craft? Don't you?
21. Teacher: What is the purpose of this traditional object? In certain areas of the country this thing is used as a fish trap. Or as a trap to catch rats. This is called... fish trap.
24. Teacher: Trap, fish trap, just like this one [he shows another model of a fish trap]. This is also a trap for fishing.

The only mathematical activity that the fish trap model asked for was classifying (it is a cone), but not for further concept formation. However, the worksheets introduced cut-outs making learners relate two-dimensional and three-dimensional shapes and discover rules (e.g. a larger sector yields a lower cone). A principal discovery for many learners was the differences between the height of a cone, and the slanting height (along the lateral surface).

One of the exercises made learners discuss how the two cones constituting a traditional fish trap are interrelated, concluded by a multiple-choice exercise, on which sectors could together make a fish trap (Figure 3). With the models given in
their hands, learners discussed intensively, holding the cones top-down, folding and opening the circle sectors again and again. Despite the intensity of discussions, the exercise was only resolved correctly by 60% of the groups.

![Multiple-choice exercise diagram]

**Figure 3:** Multiple-choice exercise: choose two circle sectors that together can be folded into a traditional fish trap (answer: B and E)

In the instructional design we had orchestrated separate components, such as the local Mozambican resources together with the group work, the open-ended questions and so forth. The interventions showed us that these components together changed the classroom dynamics. Learners could discuss mathematical concepts in their own words because they sat in groups. But the group work would not have functioned as vividly if it were not for the open-ended questions. The open-ended questions triggered interest because their topics were linked to extra-institutional experiences and made available through familiar resources.

As a result, the *learning ecology* changed in many aspects. The groups of learners sat together, working on the tasks from the worksheet. It was the worksheet that instructed them, not the teacher. Thus, the teacher became an outsider of learners’ activities. The customary class activities, in which learners follow and copy what the teacher demonstrates, were changed as the learners were assembling each others contributions within the groups. Here, the mode of dialogue changed, because learners had to explain to each other. The following excerpt shows that it was not always easy to exchange ideas within the groups:

Episode 30 (from the group interviews, Geometry Study):

23. Student A: We saw, we had different ways, but with the same destination. So, one with an opinion, another with an opinion,.....we continued to discuss, and then in the end we saw that the destination was the same!


25. Student B: We spoke of the same thing but with different words. There was some confusion when we wanted to say things...we said one thing...they used a different word to say the same thing. So it was difficult the discussion.

**CONCLUSIONS**

In this report we have presented a design research in mathematics education in Mozambique, in which shared principles were applied in two completely different settings, respectively at junior secondary and at tertiary level. Our starting point demonstrated that modern Mozambican society is rich in resources, to such an extent that it provides mathematics education with many applications. However, the resources lead to concept formation only in conjunction with a number of
instructional design principles (starting mathematics from the applications; worksheets with open-ended tasks for group work; many illustrations). The design conveyed a learning environment, in which the central role of the teacher reduced. Whole-class lecturing could be largely avoided, and discussion among learners enhanced. Pivotal in the design was the worksheet, which decentralised classroom communication and facilitated group work. This effect did not automatically emerge from the use of traditional art craft or newspaper clippings.

The interventions in this research were atypical and small-scale, yet successful in the Mozambican context of (over-)crowded classrooms. The combination of authentic resources as a starting point for concept formation and instructional design principles proved robust. These research findings could strengthen the Mozambican policies that advocate educational innovations towards more student-centeredness. Nevertheless, the large-scale enactment of these policies still has a long way to go.

References


